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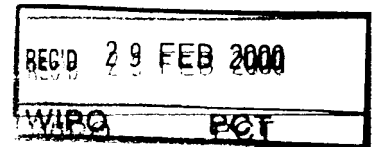
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I HEREBY CERTIFY that annexed hereto is a true copy of
documents filed in connection with the following patent
application:

Application No. S990086

Date of Filing 8 February, 1999

Applicant UNIVERSITY COLLEGE CORK, a university
established by Statute of the Republic of Ireland of
College Road, Cork, Ireland.

day of February, 2000.

An officer authorised by the
Controller of Patents, Designs and Trademarks.

REQUEST FOR THE GRANT OF A PATENT

PATENTS ACT, 1992

The Applicant(s) named herein hereby request(s)

☐ the grant of a patent under Part II of the Act

☒ the grant of a short-term patent under Part III of the Act

on the basis of the information furnished hereunder.

1. Applicant(s)

Name

UNIVERSITY COLLEGE CORK

Address

College Road, Cork, Ireland.

Description/Nationality

A university established by Statute of the Republic of Ireland.

2. Title of Invention

"Complexing agents"

Declaration of Priority on basis of previously filed application(s) for same invention (Sections 25 & 26)

Previous filing date

Country in or for which filed

Filing No.

4. Identification of Inventor(s)

Name(s) of person(s) believed
by Applicant(s) to be the inventor(s)

JEREMY DENIS GLENNON and STEPHEN JOHN HARRIS

Address

Kileden, Nova Court, Carrigaline, County Cork, Ireland, an Irish citizen, and
10 Broadford Crescent, Ballinteer, Dublin 16, Ireland, a British subject,
respectively.

CONTINUED OVER

5. Statement of right to be granted a patent (Section 17 (2) (b))

The applicant has derived the right to be granted a Patent from the inventors by virtue of a Deed of Assignment dated February 8. 1999.

6. Items accompanying this Request - tick as appropriate

- (i) ☒ Prescribed filing fee (£ 50.00)
- (ii) ☐ Specification containing a description and claims
- ☒ Specification containing a description only
- ☒ Drawings referred to in description or claims
- (iii) ☐ An abstract
- (iv) ☐ Copy of previous application(s) whose priority is claimed
- (v) ☐ Translation of previous application whose priority is claimed
- (vi) ☐ Authorisation of Agent (this may be given at 8 below if this Request is signed by the Applicant(s))

7. Divisional Application(s)

The following information is applicable to the present application which is made under Section 24 -

Earlier Application No:

Filing Date:

8. Agent

The following is authorised to act as agent in all proceedings connected with the obtaining of a patent to which this request relates and in relation to any patent granted -

Name

Address

F.F. GORMAN & CO.

54 Merrion Square,
Dublin 2,
Ireland.

9. Address for Service (if different from that at 8)

F.F. GORMAN & CO., at its address as recorded for the time being in the Register of Patent Agents. *For: University College, Cork*


UNIVERSITY COLLEGE CORK.....

Secretary & Bursar

Signed

Name(s) :

Capacity (if applicant is a body corporate) :

Date February 5. 1999

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"Complexing Agents"

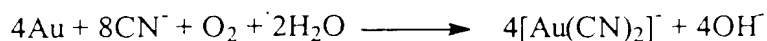
This invention relates to a complexing agent and in particular to fluorinated thiourea complexing agents and fluorinated thiourea complexing agents for use in the extraction
5 of metals such as gold.

Complexing agents are widely employed in the extraction and recovery of metals such as gold, silver and the like.

10 For example, gold is a soft yellow metal having a melting point of 1063°C with the highest ductility and malleability of any element. It is chemically unreactive and is not attacked by oxygen or sulphur but reacts readily with halogens or with solutions containing or generating chlorine such as "aqua regia". Its most common compounds exist in the (I) and (III) oxidation states.

15

Heretofore, the extraction of gold from ore and from other solid phases such as in solid phase extraction has been commonly carried out by using cyanide or thiourea as reagents. In the most commercially important method for gold extraction finely crushed ore is treated with sodium cyanide in the presence of oxygen to give a sodium gold
20 cyanide complex, which is typically absorbed onto activated carbon. The sodium gold cyanide complex can be re-extracted later and reduced to the metal, (H. Schmidbaur, Interdisciplinary Science Reviews, 17 (3), 213, 1992 and A. Sigel and H. Sigel in "Handbook on Metals in Clinical and Analytical Chemistry", Ed. H.G. Seiler, 1994 p388)
viz:

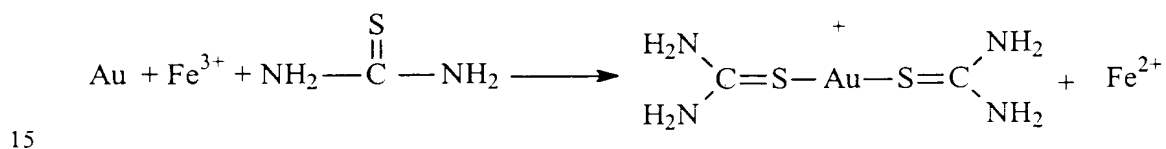


However, treatment with sodium cyanide is environmentally unfriendly while the efficiency of the reaction can be poor and variable according to the ore type.

Accordingly, other methods of gold extraction have been developed e.g. thiourea

5 based extraction. Thiourea based extractions enjoy the advantages of higher leaching efficiency, rapid leaching, adaptation to a variety of refractory ores and reduced toxicity to the environment. Accordingly, thiourea is an attractive procedure for the extraction of both gold and silver.

10 For example, it has been demonstrated (C.K. Chen, T.N. Lung and C.C. Lung and C.C. Wan, Hydrometallurgy, 5, 207, 1980) that employing Fe^{3+} as oxidant in acid solutions resulted in leaching with thiourea which was ten times faster than leaching with sodium cyanide, viz:



However, excessive consumption of thiourea in the process has limited its industrial application.

20 Various attempts have been made to reduce thiourea consumption. For example in order to reduce thiourea consumption in gold extraction it has been suggested (C.C. Kenna, Gold Bull, 24(4), 126, 1991) that the complexing of ferric ions could be utilised

in reducing their oxidative power to a level where oxidation of gold still proceeded at an acceptable rate while oxidation (and consumption) of thiourea was greatly reduced.

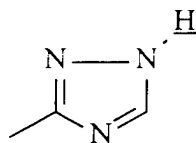
U.S. Patent Specification No. 5126038 also discloses that alkyl hydroxamic acids or their salts may be used to improve extraction of precious metals, including gold, from sulphide ores in combination with standard sulphide ore collectors such as xanthates, substituted thioureas and the like.

G. Zuo and M. Muhammed, Separation Science and Technology, 25(13-15), 1785, 1990 also describe the synthesis and characterisation of a family of thiourea based reagents for the extraction of Au(III) and Ag(I) ions through complex formation from HCl solutions and also disclose the synthesis of several co-ordinating polymers by grafting thiourea functional groups onto commercial macroporous polystyrene polymer matrices.

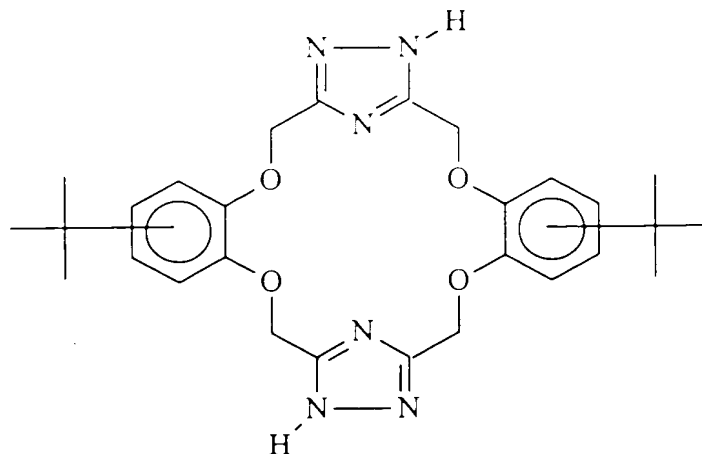
In order to avoid the use of thioureas, azacrowns have also been used to facilitate transport of $\text{NaAu}(\text{CN})_2$ into an organic phase from an aqueous phase (M. Tromp, M. Burgard, M.J.F. Leroy and M. Prevost, J. of Membrane Science, 38, 295, 1988). In addition, Izatt et al., (R.L. Bruening, B.J. Tarbet, T.E. Krakowiak, M.L. Bruening, R.M. Izaat and J.S. Bradshaw, Anal. Chem., 63(10), 1014, 1991 and R.L. Bruening, B.J. Tarbet, K.E. Krakowiak, R.M. Izatt and J.S. Bradshaw, J. Heterocyclic Chem., 27 347, 1990) have developed silica gel bound thia – macrocycles which have shown high selectivity for Au(III).

Supercritical fluid extraction (SFE) has developed into an attractive alternative to conventional solvent extraction to recover organic compounds from solids in particular. A useful fluid for SFE work is carbon dioxide due to its moderate critical constants ($T_c = 31.1\text{ }^\circ\text{C}$, $P_c = 72.8\text{ atm}$), inertness, ease of availability, low cost and ease of final
 5 removal. However, direct extraction of metal ions, by supercritical CO_2 is very inefficient due to the charge neutralisation required and weak solute-solvent interactions.

Supercritical fluid extraction of gold has been reported by S. Wang, S. Elshani and
 10 C.M. Wai, Anal. Chem., 67, 919 1995 where Au(III) ions were extracted by bis-triazalocrowns from wet solid matrices using supercritical CO_2 modified with methanol. Neutral gold complexes were formed due to the presence of triazolo protons:



which were soluble in modified SF-CO_2 . The presence of the triazolo protons was
 15 necessary for the extraction of the metal ions to give a neutral metal ion-ligand complex:



and no extraction was possible without methanol modifier or water in the solid phase.

Supercritical CO₂ has also been utilised (E.O. Out, Separation Science and Technology 32,6, 1107, 1997) to elute gold in the form of NaAu(CN)₂ previously

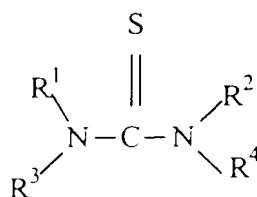
5 adsorbed on activated charcoal employing tributylphosphate to facilitate charge neutralisation. However, the presence of water in the solid phase was required for the extraction while as indicated previously the use of cyanide is undesirable for environmental and safety reasons.

10 An object of the invention is to overcome the problems of the prior art.

A further object of the invention is to provide a complexing agent or ligand for gold extraction.

15 A still further object of the invention is to provide a method for extracting gold which overcomes the problems of the prior art.

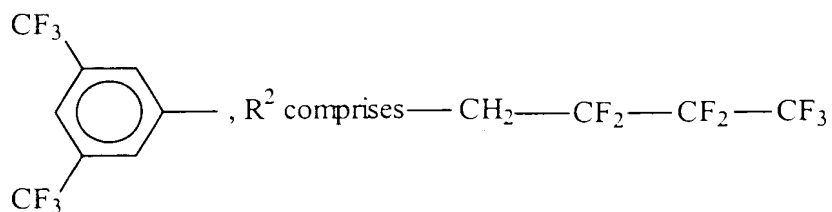
According to the invention there is provided a thiourea having the general formula:



characterised in that R^1 and R^2 comprise a fluorine containing alkyl, alkaryl, aryl or substituted derivatives thereof and R^3 and R^4 are selected from the group comprising
 5 H, alkyl, aryl, alkaryl or substituted derivatives thereof. In one aspect of the invention R^3 and R^4 are selected from the group comprising fluorine containing alkyl, aryl, alkaryl or substituted derivatives thereof. The fluorinated derivatives of the invention are extremely useful for analytical assays for the selective determination of gold levels, and for gold recovery.

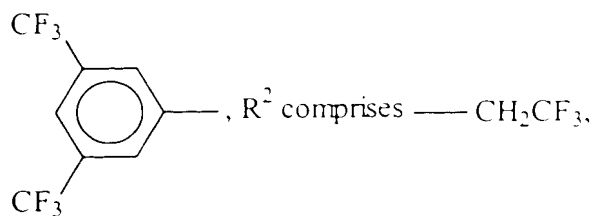
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Preferably, R^1 comprises



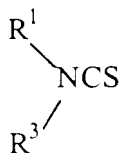
R^3 comprises H and R^4 comprises H.

15 Alternatively, R^1 comprises

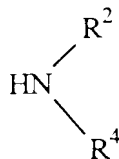


R^3 comprises H and R^4 comprises H.

- 5 The invention also extends to a method of producing a fluorinated thiourea comprising reacting a compound of general formula



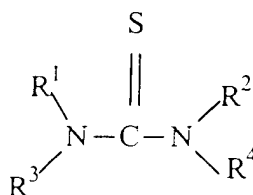
with a compound of general formula



10

where both R^1 and R^2 contain fluorine.

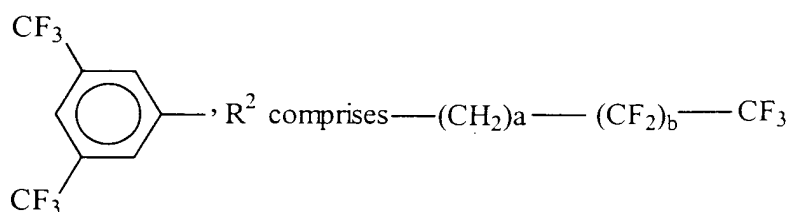
The invention also relates to a method for extracting gold from a matrix comprising treating the matrix with a thiourea having the general formula



where R^1 and R^2 comprise a fluorine containing alkyl, alkaryl, aryl or substituted derivatives thereof and R^3 and R^4 are selected from the group comprising H, alkyl, aryl or substituted derivatives thereof and subjecting the matrix to supercritical fluid extraction.

Preferably, the supercritical fluid extraction comprises CO_2 supercritical fluid extraction.

10 Preferably, R^1 comprises



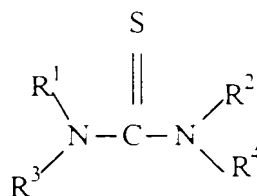
R^3 comprises H and R^4 comprises H where $a \geq 1$ and $b = 0 - 6$.

15

In one embodiment of the invention the gold is extracted in the presence of an oxidant. Suitably, the oxidant comprises Fe (III) ions.

Advantageously, $b > 3$.

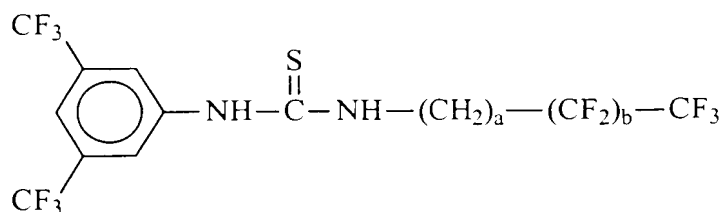
The invention also extends to the use of a fluorinated thiourea of the general formula



- 5 where R^1 and R^2 comprise a fluorine containing alkyl, alkaryl, aryl or substituted derivatives thereof and R^3 and R^4 are selected from the group comprising H, alkyl, aryl, alkaryl or substituted derivatives thereof in the extraction of gold from a matrix.

Surprisingly, it has been found that fluorinated thioureas of the general formula:

10



$$a \geq 1$$

$$b = 0-6$$

- 15 efficiently extract Au(I) and Au(III) from a solid matrix in unmodified supercritical CO_2 and furthermore may extract gold from a solid containing gold in its elemental form in the presence of an oxidant. Fe(III) ions are particularly suitable as oxidants. The addition of modifiers or protons is not required and extraction can be carried out using fluorinated thioureas alone.

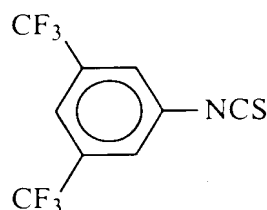
In contradistinction, thiourea itself does not form a neutral complex with gold i.e. gives $\text{Au} [\text{SC}(\text{NH}_2)_2]_2^+$.

5 In a preferred embodiment of the invention $b > 3$.

The fluorinated thioureas of the invention have a high solubility in supercritical CO_2 and are extremely efficient at solubilising and carrying gold for the purposes of extraction, recovery or impregnation.

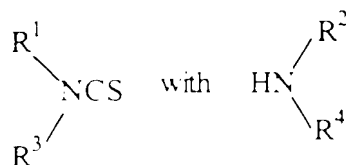
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The fluorinated thioureas can be synthesised in a simple one-step process by the reaction of:



15 with the appropriate amine $\text{NH}_2\text{CH}_2(\text{CF}_2)_b\text{CF}_3$ where $b = 0$ or 2 or 6 in a room temperature (exothermic) reaction and recrystallisation from petroleum ether (100-120) to give colourless products in 62 to 81% yields.

The compositions of the invention can therefore be formed by the simple reaction of



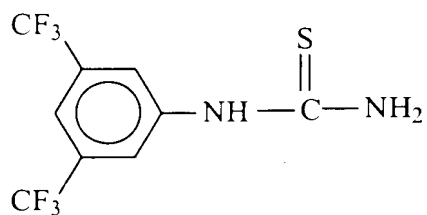
where both R^1 and R^2 contain fluorine.

- 5 Various embodiments of the invention will now be described by way of Example only, having regard to the following drawing and examples in which:

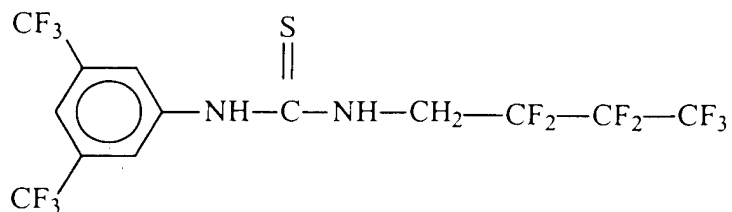
Fig. 1 is a block diagram indicating the amount of gold extracted from a geological sample on repetitive extraction with Fe(III) as oxidant.

10

Comparative Example



The aforementioned fluorinated thiourea is known from the prior art and is commercially available from FLUOROCHEM (Trade Mark).

Example 1

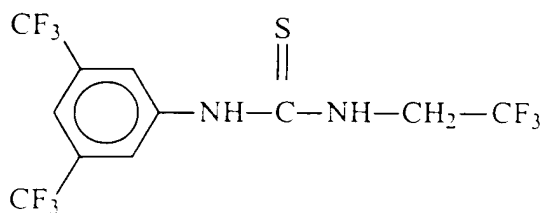
5

To 0.518 g (0.0026mole) 1H, 1H-heptafluorobutylamine (Fluorochem (Trade Mark) Product FO4396) in a round bottom flask was added 0.705g (0.0026mole) 3,5-di(trifluoromethyl) phenylisothiocyanate (Fluorochem (Trade Mark) Product F03115B). After stirring for one minute the miscible liquids solidified to a colourless solid in an exothermic reaction. After the reaction mixture had cooled it was allowed to stand for 1 hour at room temperature and the product was recrystallised from petroleum ether (100-120) to give 0.972 g of pure product (80% yield) as colourless crystals, mp 130-132°C.

15

Elemental Analysis for $C_{13}H_7N_2SF_{13}$:

Calculated: C: 33.20, H: 1.50, N:5.96, Found C: 33.05, H: 1.49, N: 6.12%

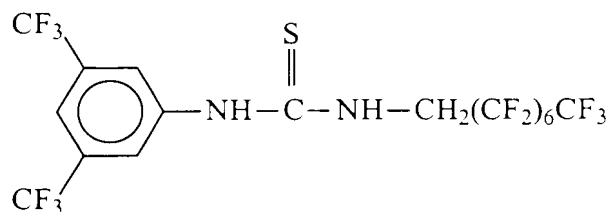
Example 2

To 0.705g (0.0026 mole) 3,5-di(trifluoromethyl)-phenylisothiocyanate in a round bottom flask cooled in an ice bath, with stirring under nitrogen, was added 0.281g (0.00283 mole) trifluoroethyl amine (Aldrich (Trade Mark) product 26,904-2). After a short period an exothermic reaction occurred to give a colourless solid. The reaction mixture was then allowed to warm to room temperature and was left for 1 hour under a stream of dry nitrogen to remove excess volatile amine (bp 36°C). The solid was recrystallised from petroleum ether (100-120) to give a pure product as fluffy colourless crystals 0.60g (62% yield).

Elemental Analysis for $C_{11}H_7N_2SF_9$:

10 Calculated: C: 35.64, H: 2.04, N: 7.55, Found C: 35.94, H: 2.20, N: 7.73%

Example 3



15 To 3.28 (0.0121 mole) 3,5-di(trifluoromethyl) – phenylisothiocyanate in a round bottom flask was added 4.82g (0.0121 mole) 1H, 1H – perfluoro-octylamine Lancaster (Trade Mark) product 16845 with stirring. An exothermic reaction rapidly ensued and after cooling to room temperature was allowed to remain for 2 hours. The white solid product was recrystallised from 100-120°C petroleum ether to give 6.50g pure product 20 (81% yield) as a colorless crystalline solid.

Elemental Analysis: $C_{17}H_7N_2SF_{21}$

Calculated: C:30.46, H:1.05, N:4.18; Found: C:30.60, H:1.16, N:4.40%

Example 4

The solubility of the ligand of the comparative Example in supercritical CO₂ was
5 compared with the solubilities of the ligands of Examples 1 and 2 in supercritical CO₂.

A weighed amount of the ligand of the comparative Example of approximately 60 mg
was placed in a glass tube (2cm x 0.5cm i.d.) and plugged with glass wool at both
ends. The glass tube was placed inside the extraction vessel and statically extracted
10 for 30 minutes. The inlet valve for SF-CO₂ was then closed and the outlet valve
opened into a collecting solution. The loss of weight of the glass tube after SFE
corresponded to the solubility of the ligand in 2.2 ml 100% SF-CO₂. The procedure
was carried out at 60°C and two different pressures namely 200 and 300 atmospheres.

15 Most of the ligand appeared to remain in the glass tube indicating poor solubility in SF-
CO₂.

Solubility of the ligand of Example 1 in supercritical CO₂:

The procedure outlined above was repeated for the ligand of Example 1. Solubilities
20 of 1.81×10^{-2} M at 60°C, 200 atm, and 3.38×10^{-2} M at 60°C, 300 atm were recorded
indicating an extremely high solubility as compared with that of the prior art.

Solubility of the ligand of Example 2 in supercritical CO₂:

25 The procedure was repeated for the ligand of Example 2. Solubilities of

$>2 \times 10^{-2} \text{M}$ at 60°C , 200 atm, and $>4 \times 10^{-2} \text{M}$ at 60°C , 300 atm were recorded again indicating an extremely high solubility as compared with the fluorinated thiourea of the comparative Example.

- 5 A number of experiments were carried out to demonstrate the extraction efficiencies of the fluorinated thioureas of the invention.

Example 5 (comparative): Supercritical Fluid Extraction of Au(III) as AuCl_4^- using the compound of the comparative Example.

10

Gold Au(III) extraction by the ligand of the comparative Example was investigated employing a BDH Gold (III) standard containing 1000 ppm Au(III) (aqueous AuCl_4^-). Thus 60 μl of solution Au(III) containing 3.05×10^{-7} moles Au(III) was applied to a 3cm diameter filter paper. The filter paper was allowed to dry and then placed in a glass

15 tube (2cm x 0.5cm i.d.), plugged with glass wool at both ends. 20mg of ligand of the comparative Example (in excess of over 200 fold over Au(III) level) was then placed in the same glass tube and plugged with glass wool. The temperature of the extraction vessel was then set at 60°C and the pressure was varied as indicated in Table 1.

- 20 The extraction vessel was statically extracted for 20 minutes and then dynamically extracted into a collecting solvent of 4 ml methanol for 15 minutes (0.8 ml CO_2 /minute flow rate). The methanol solution was then made up to 10 ml using additional methanol. Levels of gold in solution were then determined by atomic absorption spectroscopy. The procedure was carried out at different pressures from 200-400 atm.
- 25 The following extraction percentages were obtained:

TABLE 1

	Pressure SF-CO ₂ (atm)	Atomic Absorption (A.U.)*	Extraction (%)
5	200	0.000	0
	250	0.000	0
	300	0.001	0.3
	350	0.000	0
	400	0.024	6.7
10			

* The % extraction is calculated with reference to the Atomic Absorption reading obtained for 10ml of collecting solution spiked directly with 60 μ l of the 1000ppm Au(III) standard. (For example for the data presented in Table 1 a standard of 60 μ g/10 ml = 6ppm Au, gave an absorption value of 0.359, representing 100% extraction. Note such

15 recordings of standard values were carried out alongside the sample analysed on the same day.)

400 atm was the only pressure of SF-CO₂ to give detectable Au(III) extraction. In all runs most of the ligand appeared to remain in the glass tube indicating poor solubility in

20 SF-CO₂.

Example 6 (comparative)

The procedure in Example 5 was repeated except the temperature of the extraction procedure was varied from 60-120°C, while maintaining the pressure of the extractor

25 at 400 atm. The following results were obtained:

TABLE 2

Temperature (°C)	Atomic Absorption (A.U.)*	Extraction (%)
60	0.027	8.8
80	0.002	0.7
100	0.006	2.0
120	0.005	1.6

* A standard of 6ppm Au, gave an absorption value of 0.305 = 100%

The % extraction of gold remained low.

Example 7

The procedure in Example 6 was repeated with the ligand from Example 1 being used in place of the ligand of the Comparative Example. The following % extraction values were obtained at differing pressures for extraction of Au(III):

TABLE 3

5	Pressure SF-CO ₂ (atm)	Extraction (%)
	<hr/>	
	200	61.2
	250	92.7
	300	83.7
10	350	75.3
	400	78.1
	<hr/>	

Percentage extraction with the ligand of the invention was therefore excellent at 92.7%
15 compared with the poor extraction (<10%) with the ligand of the comparative Example.

Example 8

Reduction of Au(III) to Au(0) was accomplished by treatment with hydroxylamine
hydrochloride followed by sodium hydroxide.

20

The procedure in Example 7 was repeated except the conditions were altered to 60°C
at 250 atm. The 60μl of AuCl₄⁻ was replaced by 60μl of a well mixed even suspension
of Au(0) applied to the filter paper which was allowed to dry to give a black-blue colour.
The collected methanol solutions, made up to 10 ml as before, were analysed by
25 Atomic Absorption Spectroscopy as before, giving the following % extraction values:

TABLE 4

5	Pressure SF-CO ₂	Atomic Absorption	Extraction
	(atm)	(A.U)*	(%)
10	200	0.001	~ 0.0
	250	0.002	~ 0.0
	300	0.001	~ 0.0
	350	0.002	~ 0.0
	400	0.002	~ 0.0

15 Accordingly, the ligand of Example 1 did not extract Au(0). Moreover, at the end of the runs the blue-black colour of Au(0) remained on the filter paper and no ligand remained in the tube. However, as described further below the gold could be extracted following oxidation of Au(0) to either Au(I) or Au(II).

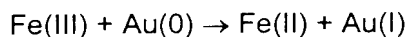
20 Example 9

The procedure in Example 8 was repeated but 40mg of solid Au(0) was used in place of the Au(0) suspension deposited on the filter paper to give an identical result to Example 8.

Example 10

The procedure of Example 9 was repeated utilising 20 mg of the ligand Example 1 except 11.2 mg of solid Au(0) was used and on two occasions the Au(0) was first oxidised to Au(I) by spiking 60 µl of Fe(III) (1000 ppm stock solution) onto the solid Au(0) directly and then allowed to dry. In the case where Fe(III) had been added when the collected methanol solution (as usual made up to 10 ml) was analysed by atomic absorption a large signal was obtained (0.252) and (0.253) indicating extraction of Au(I). Fe(III) was the limiting reagent as:

10



and therefore 60µl 1000ppm Fe(III) (1.075µmole) is equivalent to 212µl of 1000ppm Au(I) (0.2 mg Au).

15 Table 5 below outlines the results obtained following application of Fe(III):

20

25

30

35

TABLE 5

Sample	Atomic Absorption (A.U.)*	Extraction (%)
5	<hr/>	
11.2mg Au(0) + 20mg ligand of Example 1	0.001	0
10	11.2 mg Au(0) + 60 µl Fe(III) + 20mg ligand of Example 1	0.252 20.0
15	11.2 mg Au(0) + 60 µl Fe(III) + 20mg ligand of Example 1	0.253 20.0
<hr/>		
A 212µl aliquot of 1000 pp, Au(III) standard solution gave an absorption value of 1.263		
20	= 100%.	

Accordingly, Au(0) has been successfully oxidised by Fe(III) to give Au(I) which has been extracted with the fluorinated ligand of the invention. That only 20% of the theoretically freed gold (by Fe) was finally detected by atomic absorption is not surprising in view of the fact that the Fe(III) was applied as a 1000ppm aqueous nitrate solution to the solid Au(0) on the filter paper without thorough mixing.

Nevertheless, the method can be employed successfully as a qualitative test for Au(0).

Example 11

- 5 The procedure of Example 7 was repeated employing the ligand of Example 2 in place of the ligand of Example 1 and utilising 50 μ l Au(III) standard solution in place of 60 μ l to give the following % extraction results at differing pressures of SF-CO₂ at 60°C.

TABLE 6

10

Atmosphere SF-CO ₂	Extraction (%)
-------------------------------	-------------------

15

200	41
250	51
300	22
400	14

20

Example 12

- The procedure of Example 11 was repeated except Au(III) standard was replaced by
25 5.7 mg solid Au(0) and extraction was determined under previously optimised conditions 60°C/250 atm SF-CO₂. Table 7 summarises the results:

30

TABLE 7

	Sample	Extraction
5		(%)
10	Au(O) + ligand	~ 3

Example 13

15 Above Example 12 was repeated except that 30 μ l 1000 ppm Fe(III) standard (aqueous nitrate) was spiked onto the Au(0) prior to extraction with SF-CO₂ (250atm/60°C).

Table 8 below summarises the results obtained.

TABLE 8

	Sample	Extraction
20		(%)
25	Au(O) + 30 μ l Fe(III) + 20mg ligand	57
30		

The above percentage is based on the Fe(III) oxidisable quality of gold i.e. Fe(III) is the limiting reagent.

35 57% of the "freed" gold Au(I) was therefore extracted with the fluorinated ligand of the invention.

Example 14

Example 13 was repeated but Au(0) was replaced by a 5mg geological sample containing trace Au(0) ($2\text{ppm} \pm 0.3\text{ppm}$). Extraction with SF-CO₂ was carried out with repetitive additions (30mg) of ligand and repetitive additions of 50 μ l Fe(III) standard to give the following results:

TABLE 9

	Sample	Atomic Absorption (A.U.)*	Extraction (%)
10			
	Geological sample alone	0.000	-
15	Geological samples and ligand and Fe(III)		
	Extraction # 1	0.005	5.0%
	Extraction # 2	0.038	38.0%
20	Extraction # 3	0.025	25.0%
	Extraction # 4	0.011	22.0%
	Extraction # 5	0.006	12.0%

The collection volumes up to Extraction # 2 were 5ml and for Extraction #4 to #5 were 10ml. The results achieved were within accepted ranges of variance for trace analyses.

- 5 The gold can be extracted from geological samples when prior treatment with an oxidant, such as Fe(III) is used. Fig. 1 shows the amount of gold extracted from the geological sample, on repetitive extraction with Fe(III) as oxidant.

- 10 The linear fluorinated thioureas of the invention therefore have the unexpected property of extracting Au(III) in supercritical CO₂. In addition Au(I) may be extracted from Au(0) (in its elemental state) by prior treatment with Fe(III). Finally, Au(I) can also be extracted from geological sample containing gold also by prior treatment with Fe(III). The complexing agents and extraction methods of the invention are highly efficient and do not require the use of cyanides. In addition, the fluorinated thioureas of the invention facilitate the extraction of gold without excessive thiourea consumption.
- 15

Moreover, extraction of gold using fluorinated thioureas and supercritical fluid can be effected without requiring the addition of modifiers, protons and the like.

- 20 The invention is not limited to the embodiments herein described which may be varied in construction and detail.

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Amount of Au Extraction vs. Extraction No.

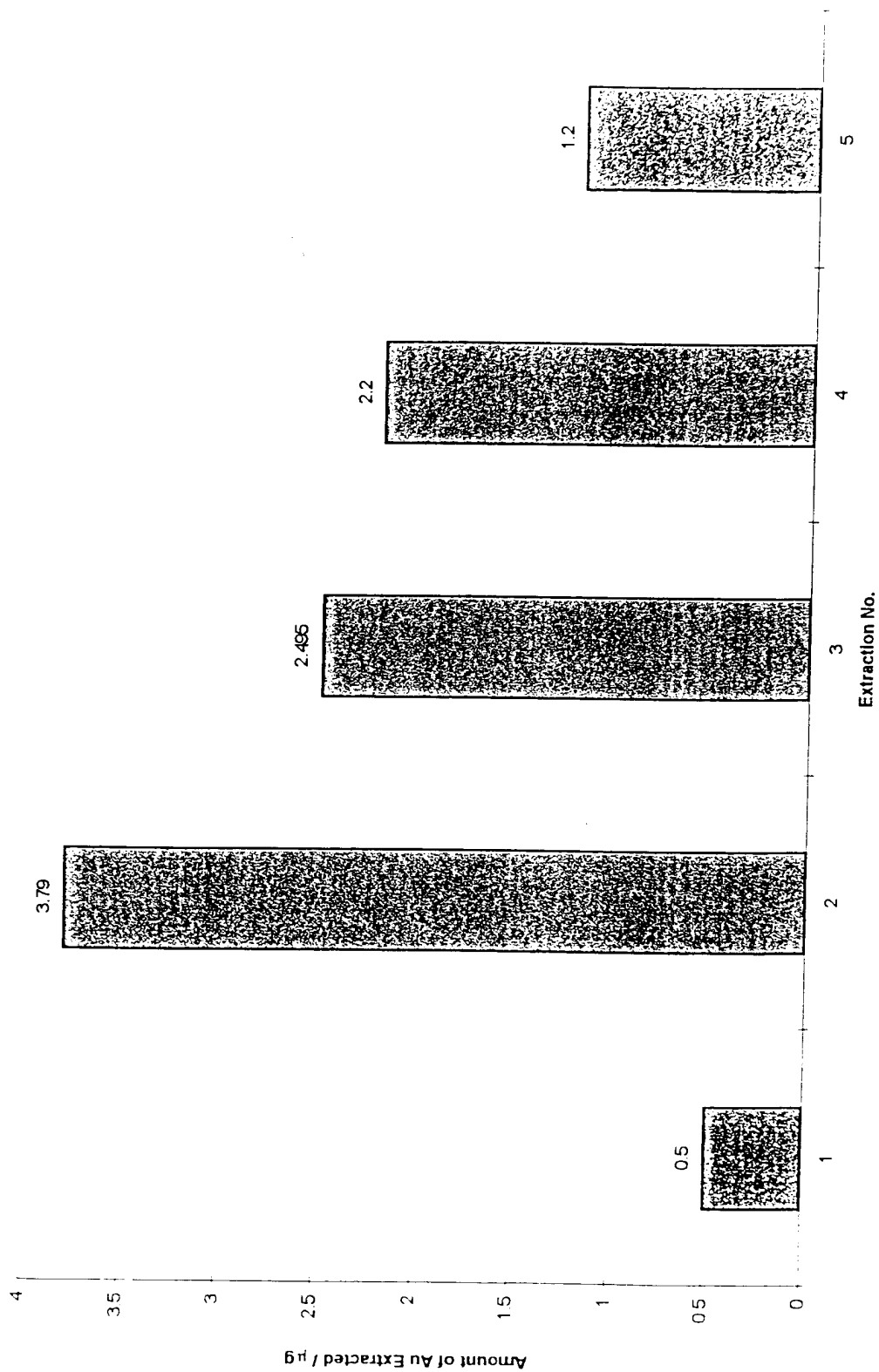


Fig. 1

